

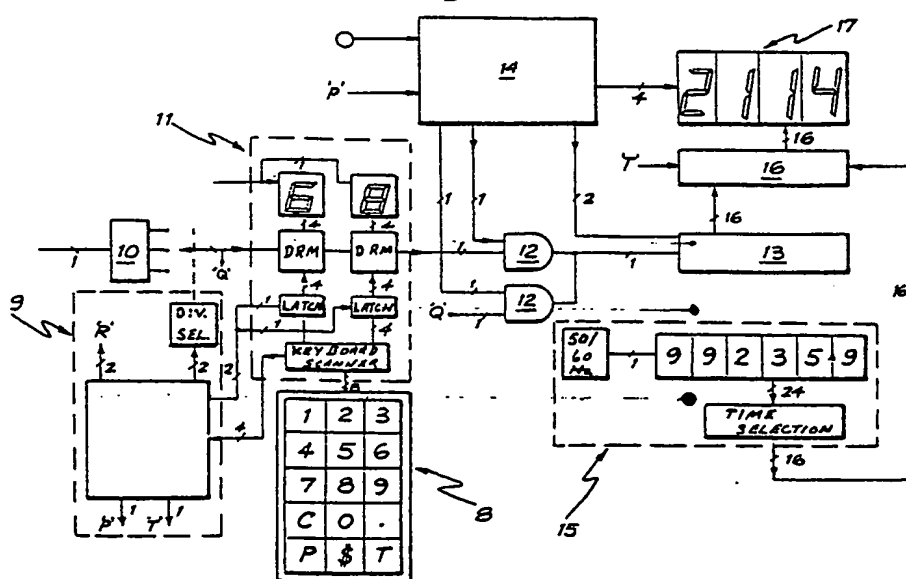


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : <b>G01R 22/00, 11/56</b>		A1	(11) International Publication Number: <b>WO 86/ 05887</b>
			(43) International Publication Date: 9 October 1986 (09.10.86)
(21) International Application Number: PCT/AU86/00078 (22) International Filing Date: 25 March 1986 (25.03.86) (31) Priority Application Number: PG 9896 (32) Priority Date: 25 March 1985 (25.03.85) (33) Priority Country: AU			(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), NO, SE (European patent), US.  Published With international search report.
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Best Available Copy

(54) Title: POWER METER WITH DISPLAY OF POWER CONSUMED AND COST OF POWER CONSUMED



## (57) Abstract

A power meter which is able to display the power consumed and the cost of power consumed over any given period. This device provides a continuous measurement of the electrical power consumed which gives a more accurate measurement than measurement at discrete intervals of time. Preferably the power meter of the present invention continuously converts the measured electrical power consumed by the load into a pulse train with its frequency proportional to the rate of power consumed, and utilises programmable digital frequency dividers (10) to provide signals to display (17) the power consumed and the cost of power consumed.

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**POWER METER WITH DISPLAY OF POWER CONSUMED AND COST OF POWER CONSUMED**

The present invention relates to electricity power meters and in particular to power meters which can be connected to the circuitry of an individual electrical appliance.

Power recording units are, of course, known, as is a meter which shows the costing of the power consumption. Such a meter is shown in U.K. Patent 2 041 588 in which the power consumption is read as a succession of discrete samples of a parameter of the mains supply, which are then fed via an analogue to digital convertor to a microprocessor operating in accordance with a stored programme. From which a signal is generated to display the power consumption and another signal to display the accumulated cost of the power consumed.

However such a device suffers from several disadvantages, the main disadvantages being the discrete sampling, and the consequential use of the microprocessor. The present invention seeks to overcome these disadvantages.

In one broad form the invention comprises a power meter adapted to continuously measure electrical power consumed by a load, which utilises input information on cost/kWh to calculate and display the total energy consumption and total cost accumulated during a time interval.

In another form the invention comprises a power meter adapted to continuously measure electrical power consumed by a load and which continuously convert the measured electrical power consumed by the load into a pulse train signal with frequency proportional to the rate of power consumed, and which calculates and displays the energy consumption and the cost of the energy consumed.

An embodiment of the present invention overcomes the beforementioned problems of the prior art by providing a power meter having a power sensor/transducer, which converts continuously electrical power into a pulse

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frequency signal, and utilizes programmable digital frequency dividers to provide signals to display the power consumed and the costs of the power consumed.

5       Electrical power meters according to a preferred embodiment of the present invention comprise:

1.       Means for continuously sensing the instantaneous power taken by the load and producing an analog output signal which continuously represents the power taken by the load;
- 10       2.       Means for producing a pulse-train signal whose frequency continuously represents the instantaneous power taken by the load, thus being less sensitive to electrical noise interference than a sampling system;
- 15       3.       A system of touch-sensor, push button or switch programmable digital frequency dividers, rate multipliers, counters and timer to calculate the energy consumption and cost over a time interval initiated by the use and with a price/kWh information input by the user.
- 20       4.       The use of decimal rate multipliers to convert kWh into cost information.
- 25       5.       Features 3 and 4 above allow the use of electronic circuits selected and designed in view of implementation as dedicated VLSI chip(s), thus ensuring a lower manufacturing cost and a higher reliability of the instrument than those using a sampling method for calculating power and energy.
- 30       6.       Touch-sensors or push-buttons or switches and digital displays to input information and display results. These features result in advantages of this embodiment of the present invention over known instruments or apparatus intended for similar applications:
  - 35       a)       Higher accuracy and reliability, due to lower sensitivity to interference of VFC based systems;
  - b)       Ease of production and lower manufacturing costs in large production runs due to ease of implementation in latest ASIC - VLSI .

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microelectronic technology.

(ASIC = Application Specific Integrated Circuits  
VLSI = Very Large Scale Integrated Circuits)

Other embodiments of the instrument of the present  
5 invention might differ in:

- the sensor type used to continuously measure the power taken by the load and produce an analog signal reflecting this power;
- 10 - the transducer type used to convert the analog signal representing the power into a pulse-frequency;
- the detailed structure of the programmable digital dividers, rate multipliers, counters, timers and displays;
- 15 - being a small, portable, self-contained instrument, inserted by the user between the appliance and the electrical load, or
- being a panel instrument, installed in an appliance, or
- 20 - being an instrument intended for switchboard installation, used for total energy metering in an installation;
- being a single-phase or a three-phase energy/cost meter.

25 The features and advantages of the present invention will now be described with reference to an embodiment for the present invention in which:

Fig. 1 illustrates schematically a block diagram of the analog circuitry of the present invention;

30 Fig. 2 illustrates schematically a block diagram of the digital circuitry of the present invention;

Fig. 3 illustrates a circuit diagram detailing one implementation of the block diagram shown in Fig. 1; and

35 Fig. 4 illustrates a circuit diagram detailing one implementation of the block diagram shown in Fig. 2.

The block diagram of the analog circuitry which performs power sensing is shown in Fig. 1. The active and neutral conductors from the mains supply form the input signal 1 of the power meter. A load (not shown)

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may be connected to the active, neutral and earth conductors of a power point 2, for example, a standard 10 amp power point. The earth conductor of the input signal 1 is connected to the earth conductor of the power point 2. The load may be an appliance, or a household circuitry, which is to be measured by the power meter and display the amount of power being consumed or its accumulated cost. The instantaneous input signal 1 is sensed with a voltage divider (in other embodiments it might be sensed with a transformer) to produce a voltage signal  $V_1$  which is proportional to the instantaneous input signal 1. For example,  $V_1 = 5$  volt corresponding to an input signal 1 of 240 volts. The instantaneous current drawn by the load connected to the power point 2, is sensed by a series resistance  $R$  connected between the neutral terminal of the power point 2 and the neutral terminal of the input signal 1. The voltage  $V_2$  measured across the series resistance  $R$  is thus proportional to the instantaneous current drawn by the load. For example,  $V_2 = 1$  volt corresponding to the instantaneous current drawn by the load. (Again, in other embodiments, it might be sensed by a current transformer.) The voltage and current signals  $V_1$  and  $V_2$  are then applied to operational amplifiers 3 and 4 to give impedance buffering such that changes in load resistance do not affect the proper circuit operation of the power meter. The signals  $V_1$  and  $V_2$  are then applied to an Analog Multiplier 5, which produces a voltage output signal  $V_3$  which is proportional to power consumed by the load. The signal  $V_3$  is then applied to a Voltage-to-Frequency Converter 6 which produces a sinusoidal signal which has a frequency which is dependant on the magnitude of the signal  $V_3$ . In an alternative embodiment, the analog multiplier and the Voltage-to-Frequency Converter may be combined in a single functional Integrated Circuit. An optocoupler 7 may then be used to interconnect the analog

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circuitry with the digital circuitry (shown in Fig. 2) whilst providing electrical isolation between the two. An optocoupler typically consists of a light emitting diode which emits electromagnetic radiation at the frequency of the sinusoidal signal, and a photo-sensitive transistor to receive this electromagnetic radiation and convert it to a pulse train for processing in the digital circuitry shown in Fig. 2.

In Fig. 2, the digital pulse train produced by the circuitry of Fig. 1 is further processed to provide a display of the energy consumed (in kilowatt hours), the power (in kilowatts), the time elapsed, or the actual cost (in dollars) of the power consumed by the load. Each of the functions may be selected on the keyboard 8. The rate, that is, the cost per kilowatt hour, is entered using the numerals on the keyboard. Any rate from 0.1 cents to 99 cents per kilowatt hour may be entered. If an error is made during entry, the clear button 'C' may be pressed and a new rate is selected. The rate selected may be automatically displayed, and used to multiply the frequency of the incoming pulse train. Once the rate is selected, the circuitry uses the value, which is keyed in, to calculate the various functions which may be displayed. The power, cost or time elapsed may be displayed by pressing the appropriate keys on the keyboard 8. The power (in kilowatts) is displayed by pressing 'P', the cost (in dollars) is displayed by pressing '\$', and the time (in days, hours, minutes) may be displayed by pressing 'T'.

The signals for displaying the power, cost or time are generated by the 'Digit Latch and Decimal Point Control Module' 9. This module is a state machine which selects the appropriate division, depending on the rate selected by the keyboard. The appropriate division is carried out by the 'Digital Frequency Divider' 10 and the 'Rate Multiplier' 11. In the Digital Frequency Divider 10, the frequency of the incoming pulse train is divided by either 1, 10 or 100 depending on the rate selected. The rate multiplier 11 converts the incoming pulses to a

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pulse train of frequency proportional to the selected rate (or cost per kilowatt hour).

The remainder of the circuitry operates on the pulse train to convert it into the desired display. This circuitry consists of two 'And gates' 12 and a '4 Decade Counter/latch' 13 both of which are controlled by the 'Gate and Counter/Latch Reset Controller' 14. The 'Gate and Counter/Latch Reset Controller' 14 also causes the reset/start and stop sequences for measuring the cost of power consumed. The '4 Decade Counter Latch' 13 accumulates the costs or energy. When the Power function 'P' is selected, the counter is automatically reset every n seconds, displaying the average power. Also provided is a timer 15 which keeps track of time from minutes to 99 days. The display selector 16 then transmits to the display 17 the appropriate signal depending on the selected keyboard function. The display consists of four 7-segment L.E.D. units and also, 4 L.E.D.s to indicate the selected display function. Alternatively a variable display can be provided to show any of the required parameters or individual displays can be provided for each of the functions.

In Fig. 3 is shown a circuit diagram illustrating one implementation of the analog circuitry as shown in the block diagram of Fig. 1.

Fig. 4 shows a circuit diagram illustrating one implementation of the digital circuitry as shown in Fig. 2. It has a keyboard, a display, a rate multiplier and a digital frequency divider shown as 8, 17, 11 and 10 respectively in Fig. 2. It is distinguished by a single Integrated Circuit, labelled as 8748 on Fig. 4 which performs the functions of: firstly, accepting the rate from the keyboard and setting the rate into the rate multiplier (shown as 11 in Fig. 2); secondly, accumulating the pulses representing the cost or power (shown as 7 in Fig. 2); thirdly, accumulating the pulses representing elapsed time (shown as 15 in Fig. 2); and finally, controlling the display to show the cost or power (shown as 14 in Fig. 2). In this implementation,

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by using VLSI custom integrated circuits, economy in parts is achieved.

5 It will be recognised by persons skilled in the art that numerous variations and modifications may be made to the invention as described without departing from the overall spirit and scope of the invention as broadly described herein.

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## THE CLAIMS:

1. A power meter adapted to continuously measure electrical power consumed by a load, which utilises input information on cost/kWh to calculate and display the total energy consumption and total cost accumulated during a time interval.
2. A power meter adapted to continuously measure electrical power consumed by a load and which continuously convert the measured electrical power consumed by the load into a pulse train signal with frequency proportional to the rate of power consumed, and which calculates and displays the energy consumption and the cost of the energy consumed.
3. A power meter according to claims 1 or 2, for continuously measuring the electrical power consumed by a load, comprising:
  - means for producing an analog signal which continuously represents the power taken by the load;
  - means for producing a pulse-train signal whose frequency continuously represents the instantaneous power taken by the load;
  - a keyboard to input the cost per kilowatt hour, a dividing means to process the pulse train such that its frequency is proportional to the rate of energy consumption; and
  - a display means to calculate and display the cost and the energy consumed by the load.
4. A power meter according to claim 3, wherein the dividing means comprises switch-programmable digital frequency dividers and digital rate multipliers.
5. A power meter according to claim 3 or 4, wherein the display means comprises gates, latches, counters, timers and their associated control circuitry.
6. A power meter according to any one of claims 1 to 5, incorporating means for continuously sensing the instantaneous power taken by the load and producing an analog output signal which continuously represents the power taken by the load.
7. A power meter according to any one of claims 1 to

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6, which uses decimal rate multipliers to convert kWh information into cost information.

8. A power meter according to any one of claims 1 to 7, making use of electronic circuitry selected and designed in view of implementation as dedicated VLSI chip(s).

9. A power meter according to any one of claims 1 to 8, incorporating touch-sensors or push-buttons or switches and alpha-numeric displays to input information and read results.

10. A power meter according to any one of claims 1 to 8, build as a small, portable, self-contained instrument, inserted by the user between the appliance and the electrical load.

11. A power meter according to any one of claims 1 to 9, built as a panel instrument, for installation in an appliance.

12. A power meter according to any one of claims 1 to 9, build as an instrument intended for switch-board installation, for total energy metering in an installation.

13. A power meter according to any one of claims 1 to 9, for single-phase or for three-phase energy/cost metering.

14. A power meter substantially as hereinbefore described with reference to the accompanying drawings.

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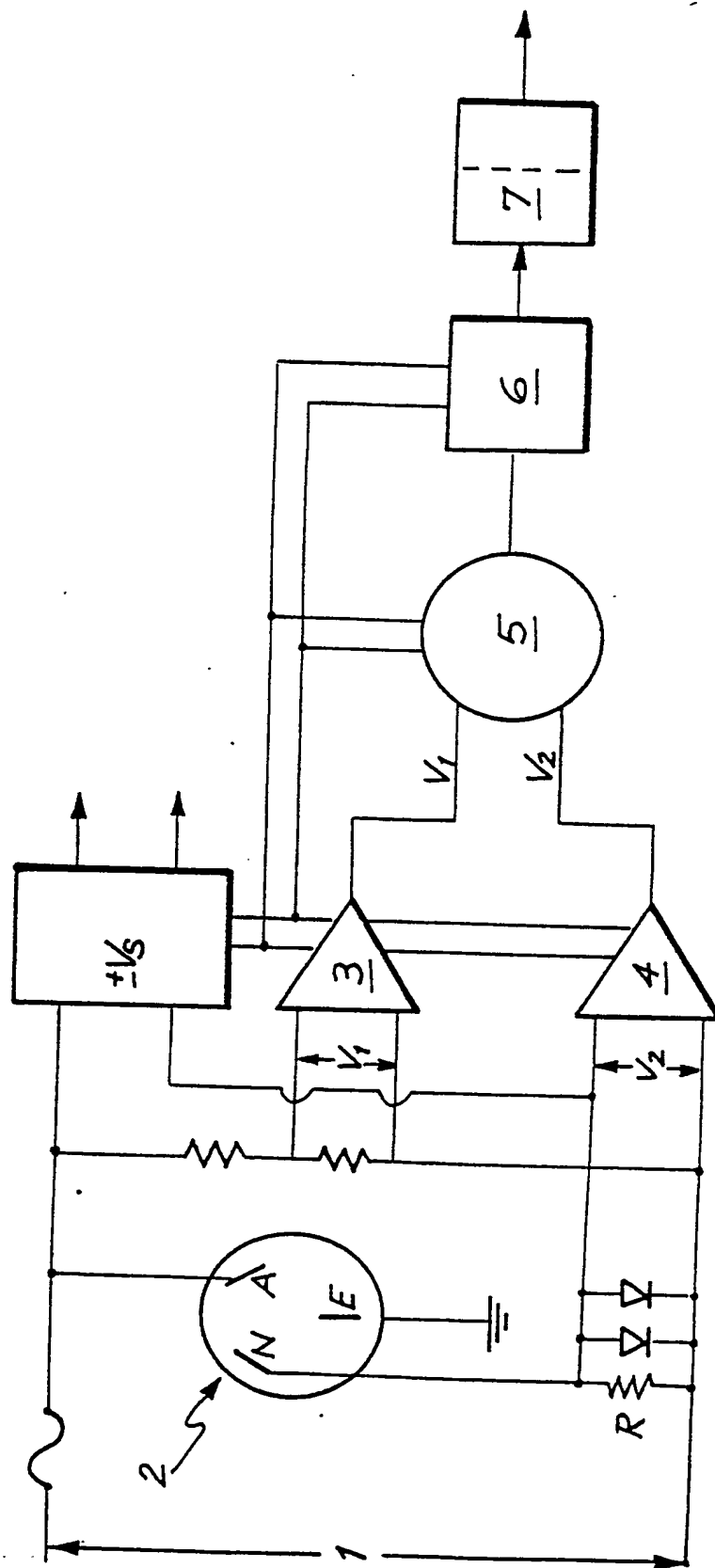


FIG. 1

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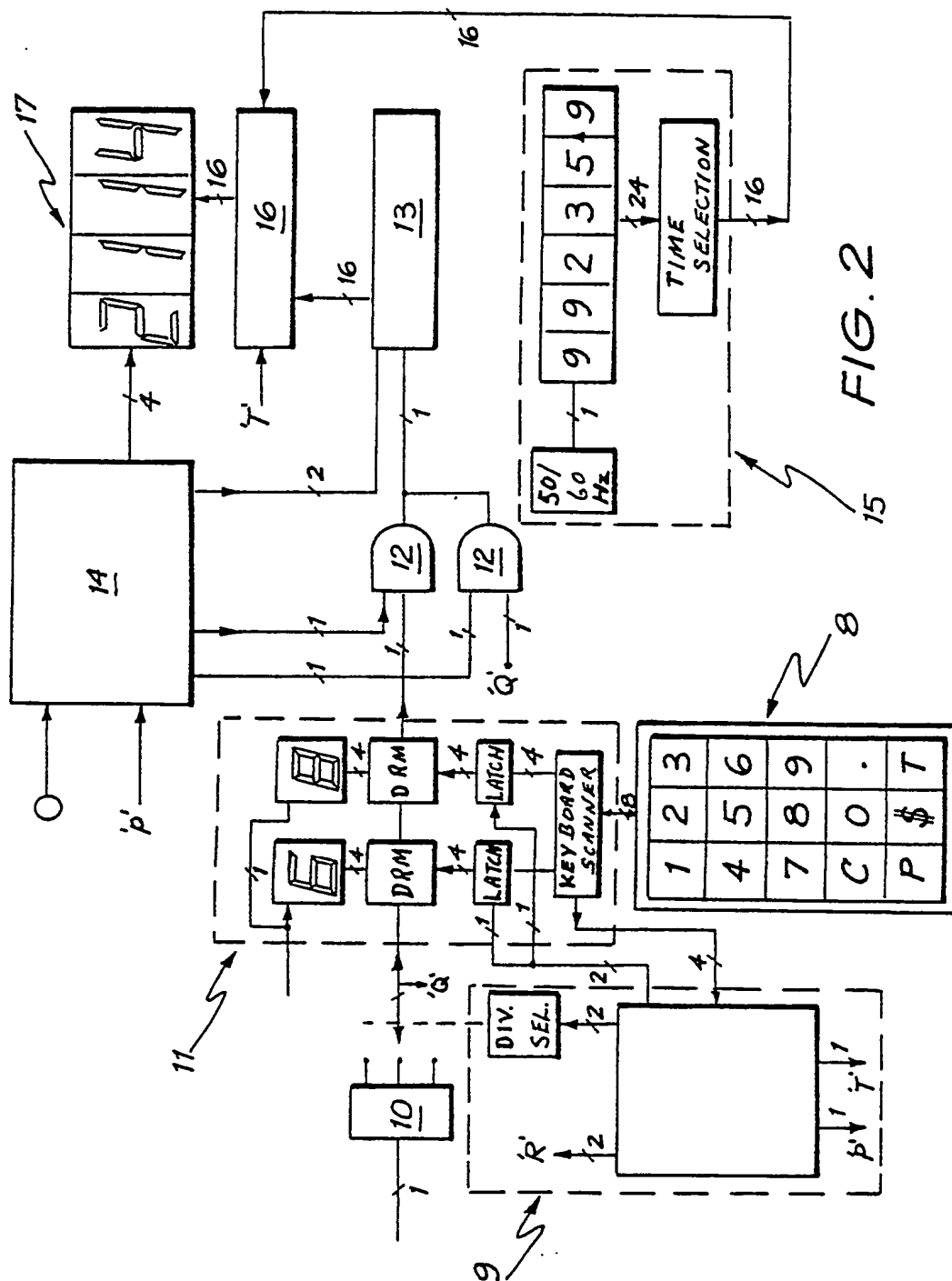
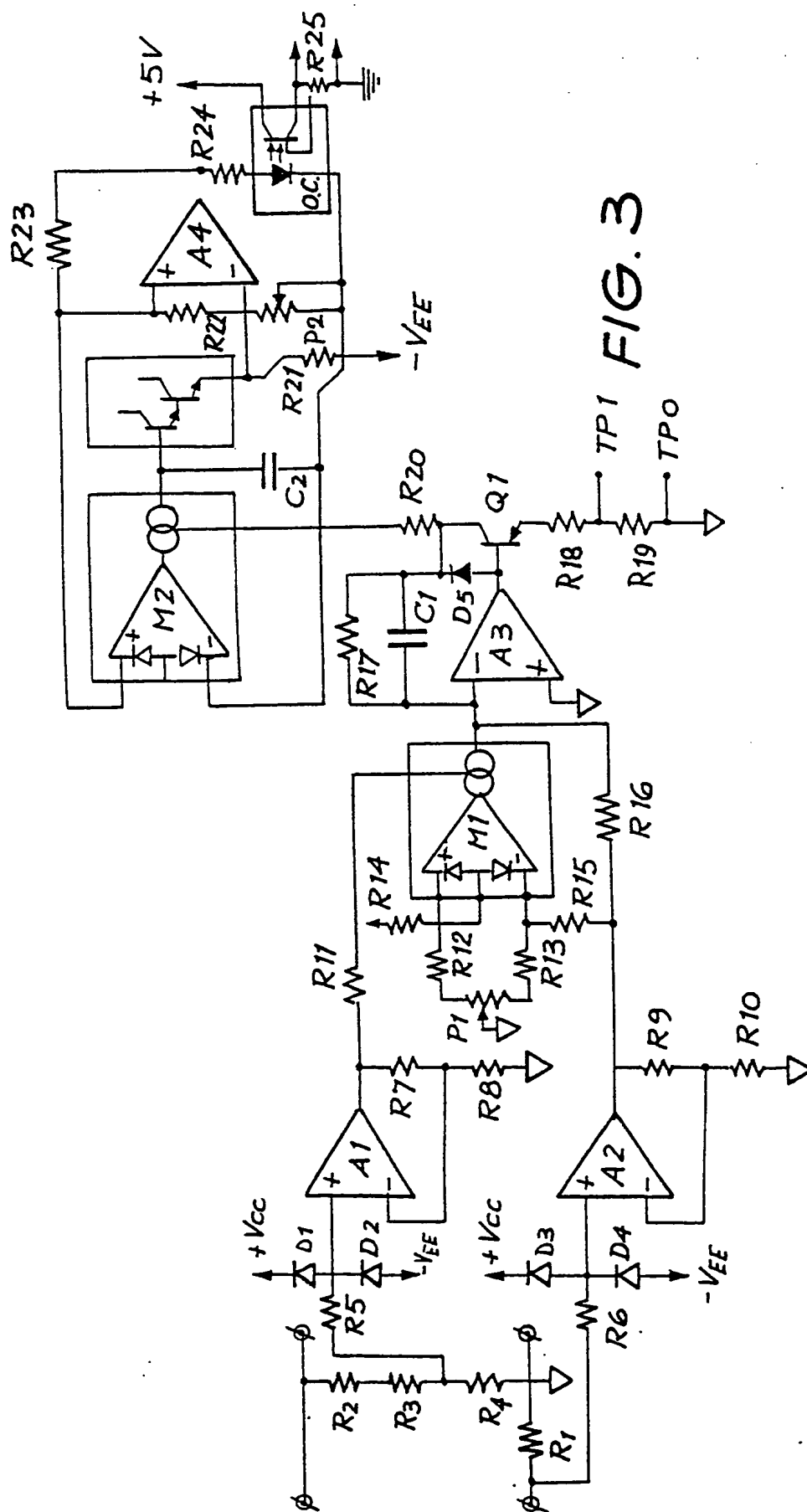


FIG. 2

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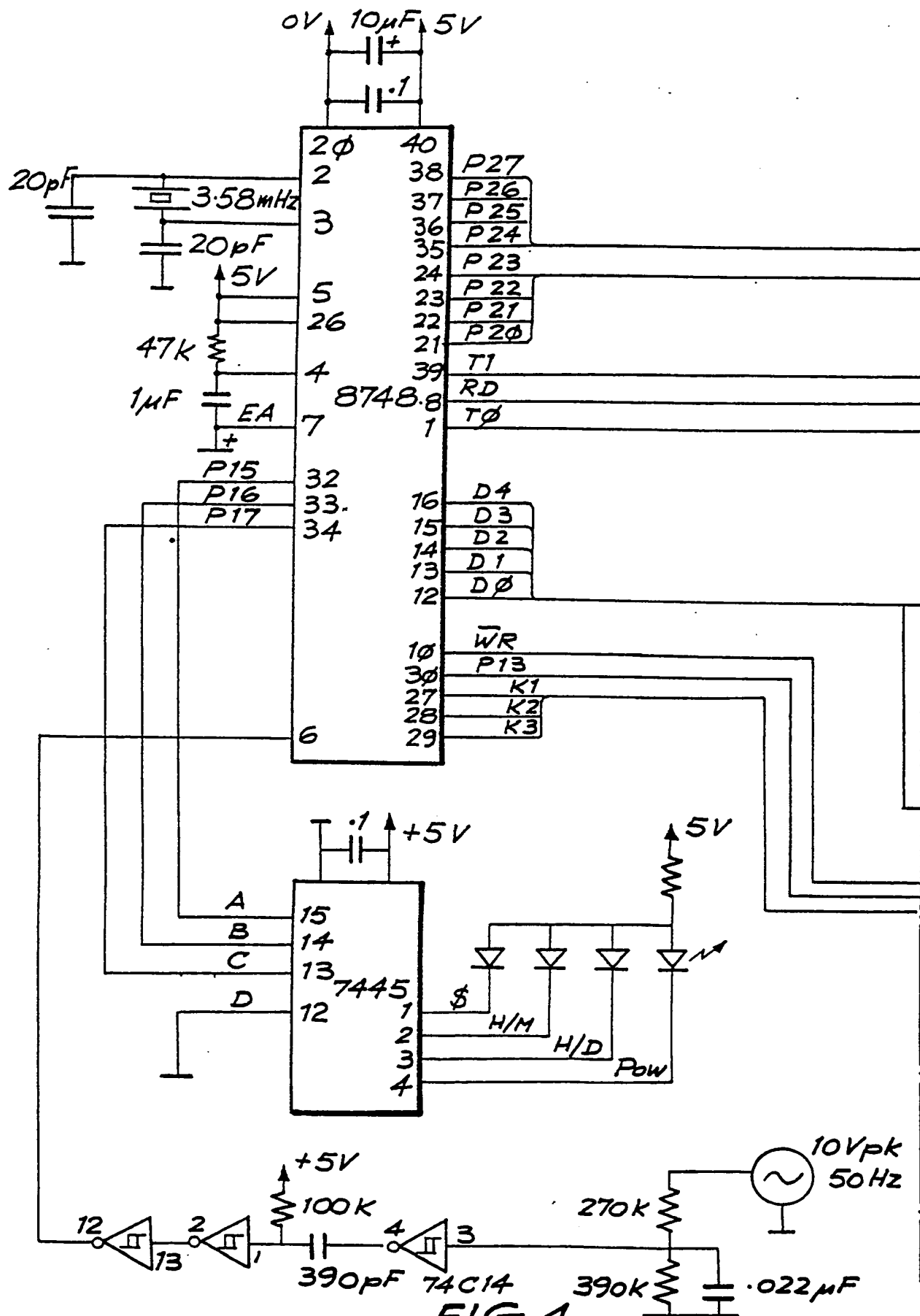
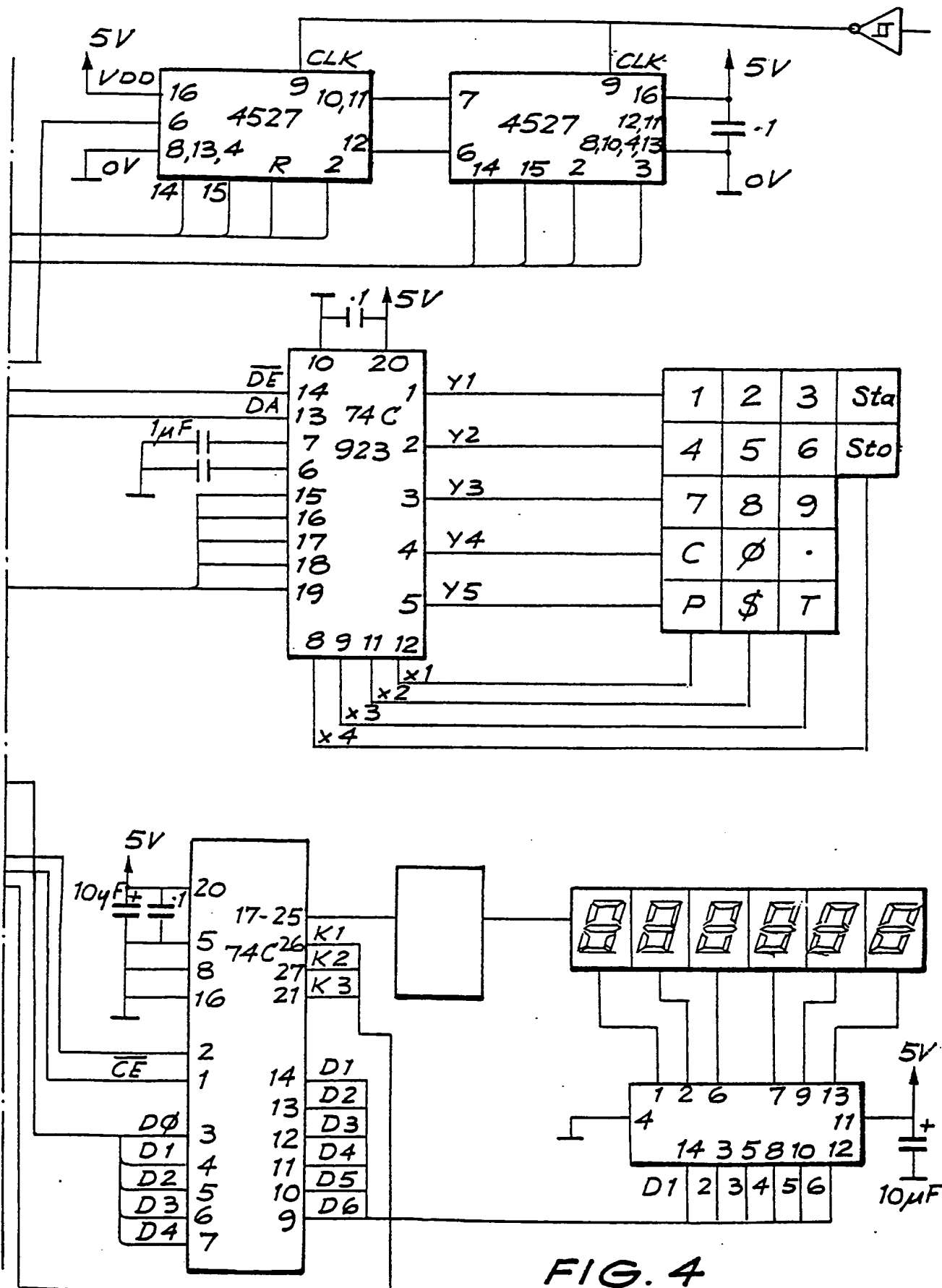


FIG. 4

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FIG. 4  
(CONTINUED)

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# INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 86/00078

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> : 1. special classification symbols apply indicate all According to International Patent Classification (IPC) or to both National Classification and IPC <div style="text-align: center; font-size: 1.2em;">Int. Cl.<sup>4</sup>      G01R 22/00, 11/56</div>																																			
<b>II. FIELDS SEARCHED</b> <div style="text-align: center; font-size: 0.8em;">Minimum Documentation Searched<sup>1</sup></div> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none;">Classification System</td> <td style="width: 50%; border: none;">Classification Symbols</td> </tr> <tr> <td style="border: none; text-align: center; padding: 10px 0;">IPC</td> <td style="border: none; text-align: center; padding: 10px 0;">G01R 11/56, 11/57, 21/133, 21/06, 22/00</td> </tr> </table> <div style="text-align: center; font-size: 0.8em; margin-top: 10px;">Documentation Searched other than Minimum Documentation to the extent that such documents are included in the fields searched<sup>2</sup></div> <div style="padding: 10px 0; margin-top: 10px;">AU : IPC as above</div>			Classification System	Classification Symbols	IPC	G01R 11/56, 11/57, 21/133, 21/06, 22/00																													
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IPC	G01R 11/56, 11/57, 21/133, 21/06, 22/00																																		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT<sup>3</sup></b> <table style="width: 100%; border: none;"> <tr> <th style="width: 10%; border: none; font-size: 0.8em;">Category<sup>4</sup></th> <th style="width: 70%; border: none; font-size: 0.8em;">Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup></th> <th style="width: 20%; border: none; font-size: 0.8em;">Relevant to Claim No. <sup>13</sup></th> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">P,X</td> <td style="border: none; vertical-align: top; padding: 5px;">GB,A, 2148565 (JEL ENERGY CONSERVATION SERVICES LIMITED (U.K.)) 30 May 1985 (30.05.85)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,9-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">GB,A, 2133594 (TAYLOR et al) 25 July 1984 (25.07.84)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">GB,A, 2041588 (DAY et al) 10 September 1980 (10.09.80)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,8-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">GB,A, 1500509 (JORDAN) 8 February 1978 (08.02.78)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,2,9-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">US,A, 4233590 (GILKESON et al) 11 November 1980 (11.11.80)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,2,9-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">US,A, 4207557 (GILKESON et al) 10 June 1980 (10.06.80)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,2,9-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">US,A, 4147978 (HICKS) 3 April 1979 (03.04.79)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,2,6,8-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">EP,A1, 15120 (SOUTH EASTERN ELECTRICITY BOARD) 3 September 1980 (03.09.80)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,8-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">WO, 82/03482 (DUPONT ENERGY MANAGEMENT CORPORATION) 14 October 1982 (14.10.82)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,9-13</td> </tr> <tr> <td style="border: none; vertical-align: top; padding: 5px;">X</td> <td style="border: none; vertical-align: top; padding: 5px;">FR, 2399028 (ELECTRICITE DE FRANCE) 23 February 1979 (23.02.79)</td> <td style="border: none; vertical-align: top; text-align: center; padding: 5px;">1,8-13</td> </tr> </table> <div style="text-align: right; margin-top: 10px; font-weight: bold;">Continued</div>			Category <sup>4</sup>	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>	P,X	GB,A, 2148565 (JEL ENERGY CONSERVATION SERVICES LIMITED (U.K.)) 30 May 1985 (30.05.85)	1,9-13	X	GB,A, 2133594 (TAYLOR et al) 25 July 1984 (25.07.84)	1-13	X	GB,A, 2041588 (DAY et al) 10 September 1980 (10.09.80)	1,8-13	X	GB,A, 1500509 (JORDAN) 8 February 1978 (08.02.78)	1,2,9-13	X	US,A, 4233590 (GILKESON et al) 11 November 1980 (11.11.80)	1,2,9-13	X	US,A, 4207557 (GILKESON et al) 10 June 1980 (10.06.80)	1,2,9-13	X	US,A, 4147978 (HICKS) 3 April 1979 (03.04.79)	1,2,6,8-13	X	EP,A1, 15120 (SOUTH EASTERN ELECTRICITY BOARD) 3 September 1980 (03.09.80)	1,8-13	X	WO, 82/03482 (DUPONT ENERGY MANAGEMENT CORPORATION) 14 October 1982 (14.10.82)	1,9-13	X	FR, 2399028 (ELECTRICITE DE FRANCE) 23 February 1979 (23.02.79)	1,8-13
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<div style="font-size: 0.8em;"> <sup>4</sup> Special categories of cited documents: <sup>10</sup>  <sup>"A"</sup> document defining the general state of the art which is not considered to be of particular relevance  <sup>"E"</sup> earlier document but published on or after the international filing date  <sup>"L"</sup> document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)  <sup>"O"</sup> document referring to an oral disclosure, use, exhibition or other means  <sup>"P"</sup> document published prior to the international filing date but later than the priority date claimed  <sup>"T"</sup> later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention  <sup>"X"</sup> document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step  <sup>"Y"</sup> document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.  <sup>"A"</sup> document member of the same patent family         </div>																																			
<b>IV. CERTIFICATION</b> <table style="width: 100%; border: none;"> <tr> <td style="width: 50%; border: none; padding: 5px;">Date of the Actual Completion of the International Search <div style="text-align: center; font-size: 1.1em;">30 June 1986 (30.06.86)</div></td> <td style="width: 50%; border: none; padding: 5px;">Date of Mailing of this International Search Report <div style="text-align: center; font-size: 1.1em;">09 JULY 1986</div></td> </tr> <tr> <td style="border: none; padding: 5px;">International Searching Authority <div style="text-align: center; font-size: 1.1em;">Australian Patent Office</div></td> <td style="border: none; padding: 5px;">Signature of Authorised Officer <div style="text-align: center; font-size: 1.1em;">R. TOLHURST</div></td> </tr> </table>			Date of the Actual Completion of the International Search <div style="text-align: center; font-size: 1.1em;">30 June 1986 (30.06.86)</div>	Date of Mailing of this International Search Report <div style="text-align: center; font-size: 1.1em;">09 JULY 1986</div>	International Searching Authority <div style="text-align: center; font-size: 1.1em;">Australian Patent Office</div>	Signature of Authorised Officer <div style="text-align: center; font-size: 1.1em;">R. TOLHURST</div>																													
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## FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

X	DE, A1, 3320253 (VIGENER) 6 December 1984 (06.12.84)	1,8-13
X	DE, 336067 (KORTING et al) 23 April 1921 (23.04.21)	1,10-13
X	DE, 334117 (KORTING et al) 9 March 1921 (09.03.21)	1,10-13

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers ..... because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers ..... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically

3. ☐ Claim numbers ..... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

## Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

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